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THE AIR LINE PILOT

In This Issue:

What Has Been Learned About The Medical Aspects Of Jet Flying?

The Air Line Pilot

FEBRUARY, 1959

Volume 28, No. 2

Entered as Second Class Matter at the Post Office at Chicago, Ill.
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ED MODES, Editor

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Published Monthly by the Air Line Pilots Association, International, Affiliated with A. F. of L.-C.I.O. Publication offices: 55th Street and Cicero Avenue, Chicago, 38, Illinois.

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Annual Subscription, $2.50.

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On the Cover

THE photograph on the cover of this issue of THE AIR LINE PILOT *was taken during the early stages of the ALPA evaluation of the Lockheed Electra. Phases one and two of the report made by the committee are in printing.*

Seen in the picture, from left to right, are Ed Taffee (NAL), Rudy Thoren (Lockheed), Ed Bechtold (EAL), Charles Merce (Lockheed), August Place (BNF), Carl Eck (ALPA), Ed Weber (AAL), Henry Dreyer (WAL), L. H. Mouden (BNF), Jack Real (Lockheed), Roy Wimmer (Lockheed) and John Stockdale (Lockheed).

During an evaluation, the committee inspects the airplane from the line pilot's point of view . . . flight evaluates the plane for performance and flight characteristics, and later service evaluation continues to determine levels of safety in line use.

The inspection goes into levels of the cockpit layout, fail safe concepts, emergency procedures, an inspection of the components and an analysis of specifications. The flight demonstration determines the plane's performance and ability to meet operational requirements, and service evaluation to further develop the plane's safety and economy under actual flight conditions.

The objective of the ALPA participation in the evaluation of new airliners is to explore the "make-up" and flying characteristics of the planes from the line pilots point of view, bearing in mind a pilot's requirements for doing his job efficiently and consistently with safety.

The committees provide manufacturers, air line operators, government representatives and other air line pilots with an opportunity to utilize the coordinated viewpoint of a representative group of active air line pilots for the common benefit of all in designing and building new, modern airliners.

Since the ALPA began aircraft evaluation in 1945, evaluations have been made on the Convair 240 and 340, Martin 202 and 404, Lockheed 1049G and 1649A, Douglas DC-7 and DC-7C, Fairchild F-27, Boeing 707-120 and Electra. Douglas DC-8 and Convair 880 evaluations are expected to be completed in the early fall.

There Is Nothing To Support Age Restrictions For Jet Pilots, Says The Author, Who Points Out Integrated Teamwork On Flight Desk Is Key To Successful Operations

Medical Aspects Of Civil Jet Air Transport Operations

By Kenneth G. Bergin

M.A., M.D., D.P.H., F.R., A.E.S.

From The Journal Of Aviation Medicine

THIS report covers the civil operation of *Comet* jet aircraft over a period of eight years, beginning with the *Comet I,* continuing with the *IIE,* to the present day with the faster long-range, more powerful version, the *Comet IV,* with which British Overseas Airways Corporation will begin trans-Atlantic operations very shortly.* With the exception of the intermission in flying following the misfortunes of some years ago, the experience covers a wide range of operations over land and sea in tropical and temperate climates, with all the problems, limitations and opportunities, which are presented in civil air transport.

The operating characteristics of the *Comet IV* are recapitulated briefly. Faster cruising (530 mph) is usually carried out at about 33,000 feet and slower cruising (480 mph) at about 40,000 feet, the average speed being approximately 500 mph. The design maximum cabin differential pressure of BOAC's *Comet IV* is 8.75 pounds per square inch. This ensures a cabin altitude of approximately 4,250 feet at an actual altitude of 33,000 feet and a cabin altitude of approximately 6,600 feet at an actual altitude of 40,000 feet.

Following on the *Comet,* BOAC will be operating the Boeing 707, followed at a later date by the Vickers VC.10, which, in its high density configuration, will carry 150 passengers non-stop for 4,000 miles at about 40,000 feet and a speed of 550 mph. It must be remembered that operating characteristics are influenced by the fact that civil air operations are, in some respects, more complicated than military because among other things, of the wide cross section of passengers carried.

Basically the *Comet* has a number of features to recommend it to flying staff and passengers alike. It is largely vibration-free, the noise levels forward of the engine tail pipe exits are relatively low, the aerodynamics are good, and its response to the controls sensitive. As a result of its freedom from vibration and its high forward speed, vertical accelerations are more noticeable, the threshold stimulus being low. The landing characteristics are good, and it is a docile aircraft in competent hands. As a result, morale of staff flying these airplanes is high, as is confidence in the airplane and its inherent airworthiness.

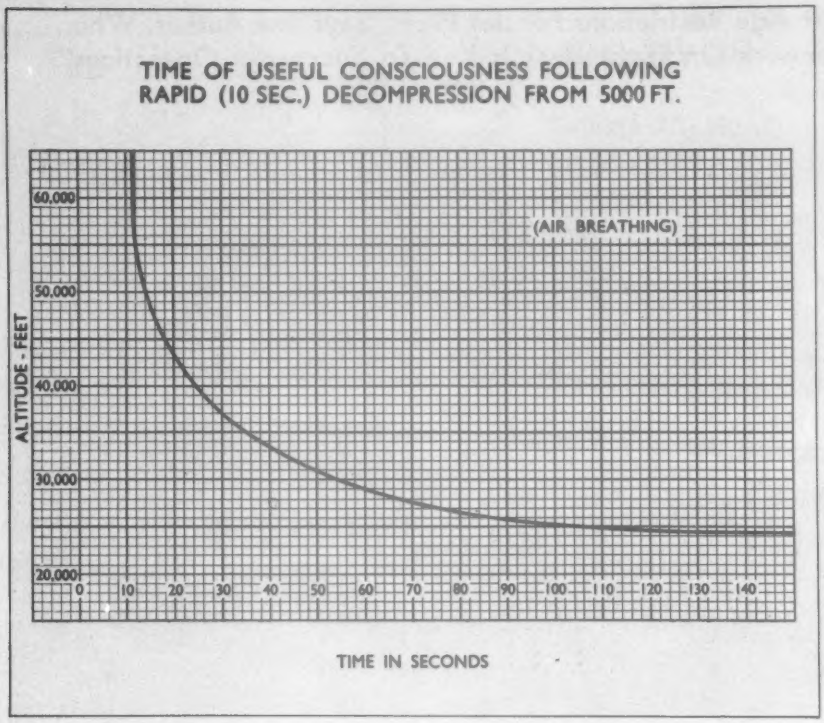
Characteristics Of Pilots

A previously held conception that pilots for jet aircraft should be of the fighter pilot mentality has been proved to be misguided and, by the same token, *any arbitrary age limit of those*

From the British Overseas Airways Corporation, London Airport, London, England. Dr. Bergin is the air line's chief medical officer.

Presented September 25, 1958 at the Third European Congress of Aviation Medicine, Louvain, Belgium.

*BOAC began jet aircraft passenger service between London and New York on Oct. 4, 1958.—Editor.



competent to fly is not supported by experience. In this connection it is important to remember that while reaction time may be slower in an older person, in the final analysis of reaction to conditions due weight must be given to the value of experience in any set of circumstances—the older and more experienced pilot carrying out his task with an economy of thought and action which is not available to his less experienced colleague. In this context, it is important to remember that conversion to any new aircraft is not easy for certain persons by reason of the complexity of techniques and learning required, to which jet aircraft are no exception; similar restrictions apply, however, to conversion to any different type of aircraft. It is important to stress here that the problems inherent in civil flying are fundamentally different in many ways from those met with in military operations. Experience has shown that failures in training are not confined to the higher age group.

Other characteristics are of importance. The pilot must be adaptable and prepared to adopt new techniques. He must be mentally alert; he must be more than usually ready to think and plan ahead and, most important, he must be prepared to be a fully working crew member. *Integrated team work on the flight deck is the key to successful jet operations.* A pilot's reaction times must be swift because he is working to a much shorter time scale and his instrument flying must be exceptionally good as instrumental approaches call for precision and accuracy. In this connection the importance of careful pre-flight training and flight stimulator work must be stressed. It was found that pilots who had concentrated conscientiously on these aspects prior to actual flying training made much quicker progress than those who did not. It is almost unnecessary to add that the physical standards required are as high as those required for any commercial pilot's license, but no special features apply.

Decompression

Decompression arises when there is any failure in the integrity of the fuselage or equipment associated with pressurization. Explosive decompression results in complete disintegration of the aircraft structure, is an irretrievable disaster, and need not be further considered. Rapid decompression, namely an equalization of the cabin pressure with the ambient atmospheric pressure, refers to an incident lasting between two and ten seconds brought about by a failure which is not catastrophic to the continued flight of the airplane.

When this takes place, a number of other things occur, the severity of each depending on the actual altitude at the time of the incident:

- A mist of condensation will fill the aircraft.
- There will be varying degrees of hypoxia leading to anoxia.
- There will be a marked lowering of temperature.

The time in which oxygen lack leads to diminished sensibility, unconsciousness and ultimately death, depends directly on the degree of hypoxia induced which, in turn, depends on the altitude at which the decompression occurs. Relevant figures in this connection are indicated in Figure 1. Experience has shown that even with appropriate indoctrination and training, several seconds may elapse before full realization of what has occured takes place. There will subsequently be about five to twenty seconds for appropriate remedial action to be taken, according to the altitude at which the incident occurs.

From these facts, the following training and operational requirements are shown to be desirable:

Thorough indoctrination of all aircrew in certain aspects of aviation physiology including lectures on physics of the atmosphere, the physiology of respiration, effects of decompression, and use of oxygen equipment, with particular reference to: (1) the physiological effects of altitude; (2) the effects of sudden decompression, including anticipated times of useful consciousness; (3) expansion of gases; (4) exposure to severe cold; (5) emergency procedures by operational and cabin staff in the event of decompression; (6) decompression sickness; and (7) otitic barotrauma.

Instructional films on the subjects outlined above, the use of oxygen and the effects of decompression and anoxia.

Demonstrations of the effects of rapid decompression by means of a decompression chamber with candidates observing the effects from outside the chamber, without being subjected to actual decompression themselves.

Instruction in the effects of decompression, including pains in ears and sinuses, with discussion as to remedial measures.

Oxygen Requirements

The following specific conditions must be considered:

▶ *Normal flight—state of readines*

—In view of the shortness of time available should rapid decompression occur, it is essential for the safety of the aircraft that oxygen should be immediately available for the pilot, co-pilot and other flight crew members in varying degree. All decisions of this sort must be a calculated risk and opinions vary between (1) the pilot being on oxygen the entire period of the flight; (2) the pilot and copilot being on oxygen at all times when the aircraft is over 25,000 feet; or (3) oxygen for the pilot, copilot and other crew members being instantly available when required. The regulations in operation in any organization are, in part, governed by the degree of flight discipline and the intelligent co-operation in such matters which can be expected from the crew concerned. In the case where the method of having the oxygen "instantly available" is adopted, the criterion by which this must be judged is if the mask can be applied in the operative position in a matter of not more than two seconds. This does not mean removing it from an adjacent hook and fixing it in position on the face. In such cases it hangs from the pilot's headset by a specially constructed harness allowing almost instantaneous application. One pilot is breathing oxygen at all times when the pressure altitude is in excess of 25,000 feet.

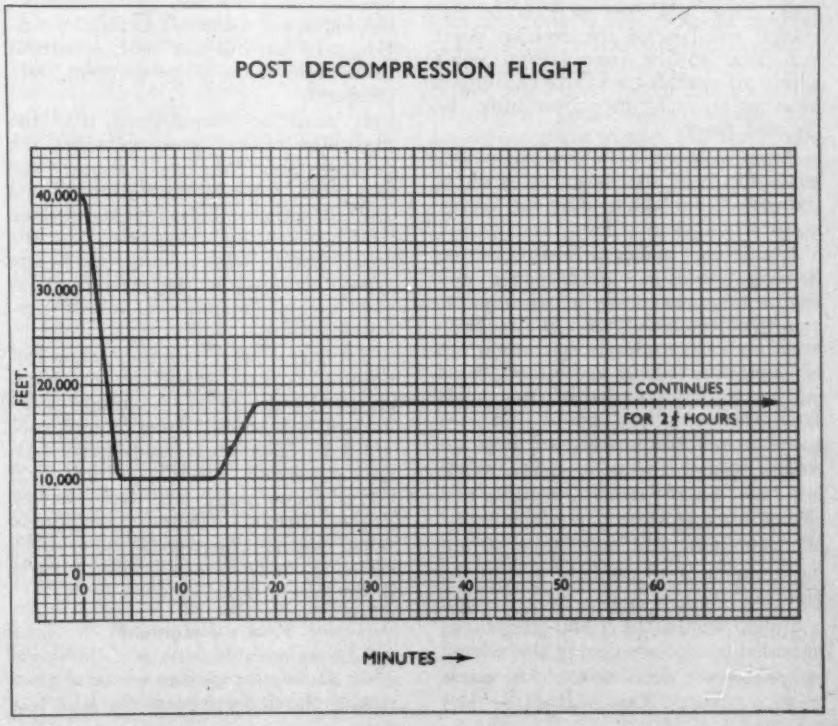
▸ *In Emergency*—This is the period immediately following a rapid decompression up to the time when descent has been completed to a safe oxygen level, namely a maximum of 10,000 feet. This time will vary with the emergency descent characteristics of the aircraft. For this period, 100 per cent oxygen should be available for all crew members, including portable walk-about sets for the catering staff. In addition, 100 per cent oxygen should be available for all passengers, including two outlets per toilet where a mother and child may be at one time.

On such an occasion, automatic barometric presentation is very desirable and is the policy adopted by BOAC, a mask of simple design falling in front of each passenger and being available for immediate application if the cabin altitude exceeds 14,000 feet. At the same time a distinctive audible warning of decompression should be provided in the cockpit for the immediate warning of the operational crew members. In this connection it is necessary to stress the importance of appropriate briefing of passengers as to this occurrence so that they are not alarmed, but reassured as to the measures taken for their safety should such an incident occur. At the same time as the briefing for emergency drill is conducted it should be clearly pointed out to them what decompression means, what phenomena may occur, and that the equipment described is provided for their safety and comfort. If properly used, it could be life-saving or at the least very advantageous to health and comfort.

▸ *Post-decompression flight*—Should decompression occur in the worst possible stage of an aircraft's flight, namely, at its greatest altitude and at the point of no return over a long over water flight, it will be necessary, after the pilot has brought the aircraft down to safe oxygen levels, to replan the flight to the nearest airport, at the altitude at which the aircraft will have to fly if it is to reach its destination with fuel available, bearing in mind that jet engines operate much more economically at higher altitudes. This decision must and can only be based on engineering and operational considerations rather than medical ones, however vital the latter may be. A typical post-decompression flight plan is illustrated in Figure 2. It may well be that post-decompression flight has to be carried out between 18,000 and 23,000 feet at which altitude symptoms of hypoxia and anoxia would be experienced by the majority of passengers, quite apart from the diminished efficiency which would be experienced by the pilot and other flight deck members. Oxygen should thus be available for the flight crew for the entire period of the post-decompression flight and for an agreed percentage of passengers. It is very difficult to come to a decision as to the amount of oxygen which should be available for passengers, because if extreme measure were taken the weight penalty could be so great that no passengers would be carried. Furthermore, it can confidently be assumed that a reasonable proportion of passengers, if they remain quietly seated, would not require oxygen at all and in any case aircraft are rarely filled to 100 per cent of their maximum load factor in the highest density configuration. Unless and until all such requirements become mandatory it will be the responsibility of each air line to provide such oxygen as it feels morally bound to do to meet the exceedingly rare combination of such an event occurring at the worst possible time and height with the maximum number of passengers in the greatest density configuration.

▸ *Equipment in Comet Aircraft*—A pressure-demand system is fitted for the flight crews. During descent from 40,000 to 15,000 feet at an emergency rate of 7,000 feet per minute, the aver-

(*Continued On Page 14*)



The Last Resort Point Is Not A Return To The GO-NO-GO Procedure, But Is The . . .

Point Of Decision

By L. K. Collins

Performance Engineering Branch, SAC
Combat Crew

TO GO or not to go has always been the $64,000 question. The problem is why and when should the normal "go" situation change into an "abort" situation.

The procedure for monitoring and checking takeoff performance has perhaps been more controversial and has undergone more changes than any other phase of operating an aircraft. Various methods of computing a decision point, or points, have been used—none of them entirely satisfactory. In January of this year, SAC adopted a single point decision procedure to replace the go-no-go concept. This method was approved by ARDC for publication in flight handbooks.

As experience progressed, however, it became apparent that even the single point decision procedure as simple as it was, left an undesirable area. This was that portion of the takeoff roll beyond the decision point but prior to the max refusal point where an aircraft could still be stopped in event an emergency arose after the decision point.

Before going into the new procedure, let us flip back the pages and look at the reasons for abandoning the go-no-go method.

It was the practical aspects of the go-no-go procedure rather than any engineering inaccuracy or incompleteness that persuaded SAC to change to a different procedure. In three years of operation several serious accidents and near-accidents resulted from pilots attempting to abort takeoff using the go-no-go procedure. Most of these accidents and incidents probably would not have happened if the pilots had elected to aggressively continue takeoff. Something had to be done to put more emphasis on the "go" side of the picture.

Stated simply, the go-no-go concept provided two points during the takeoff roll where the decision could be made to go or abort. One was at or just short of the last position from which the aircraft could possibly be stopped on the runway (go-no-go point), and one was 2,000 feet short of this point (acceleration check point). The flight handbooks instructed that the takeoff should be aborted if an engine failure or similar emergency occurred before reaching the go-no-go point, or if the speed was below that allowable at the go-no-go point. This system was fine theoretically, but actual experience proved the go-no-go point was too late in the takeoff roll to be used for anything but a "last resort" type reference point. In other words, if the pilot were to initiate an abort at or near this point, he could not be fully assured of stopping safely. There were a number of reasons for this, such as failure of the brake chute to operate properly, improper wheel braking, variable pilot reaction time, different-than-planned runway surface condition, and last but not least, erroneous calculation of the go-no-go point and/or speed.

It must be remembered that the maximum refusal speed on which the go-no-go point was based assumed the maximum stopping capability of the aircraft and associated braking devices. The acceleration check point, on the other hand, was usually too early (speed too low) in the takeoff roll to yield a good indication of takeoff performance.

Experience revealed two other important factors which greatly influenced the design of the single point decision procedure. These factors were (1) a jet engine practically never fails during takeoff, and (2) critical field length is normally less than runway length, thereby making it possible to safely continue the takeoff even in the event of engine failure relatively early in the takeoff roll.

Pilot's Judgment

The undesirable feature of the single point decision procedure was that after passing the decision point the pilot was committed to continue the takeoff even though under some conditions the subsequent loss of an engine, or similar emergency, could make it impossible to complete the takeoff. In other words, it denied the pilot his use of judgment in re-evaluating his decision in the event of an emergency which could arise during a period when the aircraft could still be safely stopped. In order for the pilot to be able to properly re-evaluate his decision during this period, the takeoff monitoring procedure must provide the last point from which the aircraft can possibly be stopped on the runway.

New Procedure

The new procedure provides this point. It is called the "last resort point" and is the marker at or just short of the maximum refusal distance. As its name implies, the last resort point is to be used only when evaluating an extreme emergency and is not to be used as a speed check point. This means that only if an emergency warranting an abort occurs at or near the last resort point will stopping be critical.

The new procedure, then, is the single point decision procedure with the last resort consideration added. It utilizes a single fixed point on the runway at which the speed check (performance check) and, normally, the decision to continue or abort the takeoff are made.

This point is called the "decision point," and is the marker nearest to one-third of the runway length from the starting end.

This means that on SAC runways the decision point is the third marker from the starting end of all runways less than 11,000 feet in length and the fourth marker from the starting end on all runways 11,000 feet and longer. The fact that it is a fixed point on any given runway greatly simplifies the computations necessary before takeoff, thereby reducing the possibility of error.

The speed required at this point is the "decision speed" and is determined very simply from the data presently in the flight handbook. The speed tolerance is applied to the decision speed as previously with the go-no-go speed. If any emergency develops before passing the decision point, or if the decision speed is not attained upon reaching the decision point, the takeoff should be aborted.

If an emergency develops after passing the decision point, the pilot must be prepared to quickly evaluate the emergency and then decide whether to

continue or abort the takeoff. To properly re-evaluate the situation, the pilot should be keenly aware of how the aircraft's stopping capability becomes more critical (and less reliable) as it progresses from the decision point to the last resort point. He should also be aware of the aircraft's ability to continue after an engine failure. This, of course, depends on the relationship of the critical field length to the runway available. If the critical field length is planned equal to the runway length, the earliest point that an engine could fail and the takeoff be safely continued would be at the last resort point. If the runway length is greater than the critical field length, an engine could fail prior to the last resort point without jeopardizing the aircraft's ability to safely continue the takeoff.

It must be emphasized that there is only one point at which thrust and airspeed are measured. This is at the decision point. The last resort (stopping) point is not provided as a further check on performance but rather to provide a known max performance stopping capability after the decision point. The point is deliberately called "last resort" because it implies that everything must work properly to get the machine stopped in the remaining runway.

One Variation

This new procedure is illustrated in Fig. 1, which shows a typical speed-distance profile of a takeoff. The relationship of the decision point to the last resort point can be seen. The decision speed tolerance, which is available because the runway available is greater than the critical field length, would reduce the decision speed shown but for presentation purposes it was not applied. The non-critical stopping performance required from the decision point and the critical stopping performance required from the last resort point are clearly indicated. The ability to continue after an engine failure is also shown.

As with most other procedures, there is a noteworthy variation. The variation here is for the B-47 aircraft at gross weight below 140,000 pounds. At these very light weights it is likely that the B-47 stopping capability will be critical if a decision were made to abort at the decision point outlined above. This is because of the relatively high speeds attainable and the relatively poor stopping characteristics of the B-47 aircraft. Therefore, the decision point for B-47 aircraft at gross weights below 140,000 pounds is at the 2,000-foot marker. This sounds like an unreasonably early decision point

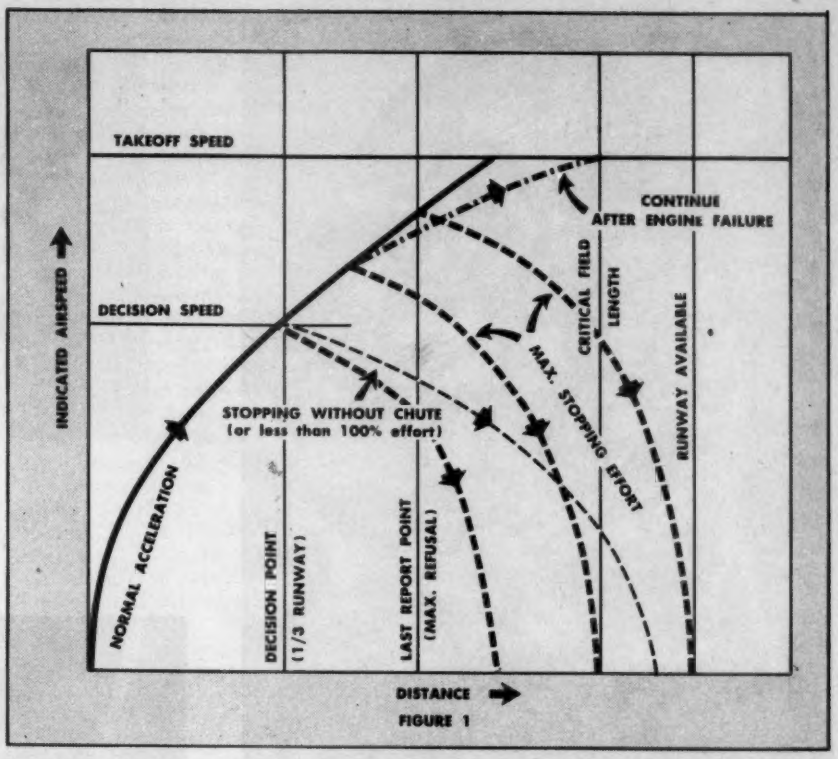


FIGURE 1

until you look in the flight handbook and find that even under the worst temperature and altitude conditions the five-engine takeoff distance at 140,000 pounds gross weight is only 7,700 feet.

Selection of the marker nearest the one-third runway point as the decision point was made after a thorough analysis of the accelerate-stop characteristics of the B-47, B-52 and KC-135 aircraft. Within the requirements of standardization and simplicity, it is the point most applicable to all three aircraft. It fulfills a basic requirement in that the ability to stop is not critical in the event the decision is made to abort the takeoff.

Until the decision point is passed, safe stopping capability is assured under normal, dry runway conditions, even if the brake chute fails to deploy. In fact, this was the primary criterion on which selection of the decision point was based.

Stopping capability from the decision point may be marginal, as before, on wet or icy runways at light gross weights and/or low temperatures and field pressure altitudes; but under these conditions there will be little likelihood of an abort at the decision point because of the decision speed tolerance allowable. At the decision point the computed decision speed will be sufficiently high to give a reliable indication of how the takeoff is progressing. It will seldom be less than 105 to 110 knots indicated for the B-47, B-52, and KC-135 aircraft.

It must be fully understood by multijet crewmen that this procedure is not a return to the go-no-go method. The difference is simple but extremely important. Using the go-no-go system, crews used that point as a further check of performance before they made any plans to stop. History proved this was too late in the game to consider stopping except under critical conditions that precluded takeoff. The new system provides a point for making this decision earlier; and only in the event factors affecting takeoff should change after this point should a stop consideration be entertained.

Another point also becomes crystal clear: indecision or an improper decision can kill you as quickly as a poor procedure. When you line up for takeoff be thoroughly familiar with the factors that affect both continuing takeoff or aborting takeoff so that you can arrive at a positive and proper decision at any point in the roll. Be sure your copilot is equally familiar with these factors and will help, not hinder, your actions. Decide from the performance of your aircraft what you must do, then aggressively pursue that course of action with everything at your disposal.

This Is What Hail Did To A Plane . . .

Hail And Thunderstorm Damage

By
Howard W. Fleming
EAL, 18

. . . This Is What Lightning Can Do

A Study Of Damage Caused By Atmospheric Phenomena And Means Of Reducing It

PILOTS who handle heavy aircraft in weather are familiar with the danger of atmospheric phenomenon acting on an aircraft as it moves through the air.

Most experienced air line pilots have been seated in "the front office" with St. Elmo's fire dancing across the ship's windshield. He has glanced out of the side window and has seen two propellers which look like Fourth of July pinwheels. Then, turbulence! He reduced engine power and began the battle to maintain altitude and airspeed. There was a blinding flash, an explosion, and the cockpit was filled with the smell of ozone. A lightning strike! He automatically checked for damage. He was flying his aircraft in a thunderstorm, or a cumulo nimbus cloud.

Questions The Pilot May Ask

The pilot probably asked himself many questions during this flight. What damage did the lightning strike do to his aircraft? He may remember the airplane has an acceleration limit load factor of +2.5g and a negative limit load factor of —1g. Have these limits been exceeded? If so, what effect did it have upon his airplane? Can turbulence force an aircraft to the ground?

Atmospheric phenomenon: thunderstorms, water-spouts, tornados, and clear air turbulence are hazards to aircraft in flight. People who are in the aviation business should understand what damage these phenomenon can cause and what means may be employed to reduce the damage. This is the purpose of this paper.

My investigation has necessarily been limited. It is limited to air carrier aviation operating fixed-wing aircraft

with a gross weight of 12,500 pounds or more. I've considered accidents of aircraft in flight between terminals and omitted accidents of aircraft in the process of takeoff and landing.

The study revealed that all of the accidents were caused by lightning, turbulence, or hail. Civil Aeronautics Board records show that the greatest number of accidents reported were caused by lightning. Lightning damage was minor, consisting of burned holes or damaged radio equipment. Turbulence was more serious and was a factor in the destruction of seven aircraft during the past five years. Hail damage consisted of cracked windshields, dent in sheet metal skin, and holes in fabric surfaces.

What The Record Shows

During the five year period from 1953 to and including 1957, the records of the Civil Aeronautics Board showed the following:

- Total air carrier accidents 346*
- Total air carrier accidents caused by atmospheric phenomenon 68
- Percentage of total accidents caused by atmospheric phenomenon 18.7%

About one-fifth of the air carrier accidents were caused by atmospheric phenomenon. Fifty of these were caused by lightning, sixteen by turbulence, and three by hail. I was surprised to find that lightning caused 72 per cent of the accidents of this kind during the period studied.

What is lightning? "Generation of strong electrical gradients is a characteristic phenomenon of thunderstorms. When the gradient exceeds a certain critical value, a crash discharge occurs."[1] This discharge is lightning.

Effects Of Lightning

Eighty-one aircraft received lightning strikes during the period of 1952 through and including 1956, and thirty-seven of these aircraft had radio equipment damaged. Radio equipment probably presents a path of least resistance for lightning. A lightning strike should alert a pilot to the possibility of radio damage.

Lightning causes aircraft compasses and electrical instruments to malfunction. In 1952, a Pan American airliner reported that a lightning strike caused the fire warning to come on, on all four engines. Investigation showed no evidence of fire. Reports of compass errors of twenty to forty degrees were sometimes experienced after a lightning strike. In one case, parts of the aircraft were magnetized causing the magnetic compass to give erroneous readings.

Airframe damage resulted in fifty-one of the eighty-one lightning strikes studied. Wings, rudder, elevators, and ailerons were damaged more often than the fuselage. Out of the fifty-one lightning strikes thirty-three caused damaged control surfaces. As an example, the aileron lead balance weights were melted by lightning in 1953. A Seaboard and Western Airliner reported a skin hole ten by four inches on top of the left wing of a Constellation after a lightning strike.

I could find no evidence of an aircraft being destroyed by lightning. This is probably because the aircraft is well bonded and the skin—being a conductor—acts as a shield and simply allows the electrical discharge to flow around it. St. Elmo's fire or corona discharge is more common and is harmless. It is caused by solid precipitation forms striking the aircraft which induces a charge. When this charge becomes great enough at points of concentration such as propellers, nose, and wing tips, it causes a continuous discharge. The aircraft charge may act to strengthen the electric field in the cloud and can result in a crash discharge. This may be why some people can predict when a discharge will occur by the amount of St. Elmo's fire present.

Reducing Lightning Strikes

We could avoid lightning by avoiding thunderstorms. However, an air line pilot sometimes finds it impossible to do this. When thunderstorms are unavoidable, lightning strikes may be reduced by the following:

- First: Avoid areas of rain by using airborne radar to circumnavigate it. "The electric field associated with a thunderstorm is weakened outside the cloud and reaches its maximum intensity in the main area of the cloud."[2]
- Second: Make every effort to avoid thunderstorms which are approaching the mature stage. Temperature of —21°C are required before initiation of lightning. "The maximum cell height, the minimum temperature at the cloud top, and maximum lightning frequency occur together."[3]
- Third: Avoid altitudes of 12,000 feet or above. The Thunderstorm Project reported the greatest number of strikes at 15,000 feet, and the highest gradient was measured at 12,900 feet.

Turbulence

Turbulence is a sequence of vertical or horizontal motions of air. Two classes of air motion are draft or sustained currents and gusts which are irregular variations within a draft. Turbulence is caused by the following:

- In cumulus buildups, it is caused by buoyancy forces created by temperature and density differences within an air mass.
- Strong wind over mountains create mechanical lifting and turbulence which may or may not be accompanied by clouds.
- Often cumulus clouds are associated with fronts; however, if the air mass is dry, clear air turbulence may exist.
- Clear air turbulence is often associated with the boundary zone of a jet stream or with an overriding wind of different direction and/or velocity.

Effects Of Turbulence

During the five year period studied, there were sixteen accidents attributed to turbulence. This was 23.5 per cent of all accidents caused by atmospheric phenomenon. Civil Aeronautics Board records show seven aircraft destroyed, two substantially damaged, and seven with minor damage. Where the damage was substantial or minor, the cause was easily established. However, in accidents where the aircraft were destroyed, the cause was difficult to establish.

Evidence indicates that loss of control occurred in all cases where aircraft were destroyed. This does not necessarily indicate pilot error due to instrument flying technique. Instead, I believe that we have a great deal to learn about weather hazards. I found only one case where structural damage preceded loss of control. This occurred in the accident of a C-46 which was flown into a severe thunderstorm in 1953.

In that accident, the outboard trunnion supporting of the right aileron tab motor backed out of the support bracket due to inadequate safetying. The tab motor then tore loose from its bracket and punched through the wing. The conditions resulted in a tendency of the aircraft to roll, and in conjunction with the extreme turbulence, caused the loss of control and subsequent overloading of the wing to a point of failure. In February, 1953, a National DC-6 crashed after entering an area of turbulence and waterspouts in the Gulf of Mexico. Civil Aeronautics Board evidence indicated structural failure before water impact.

*Less Alaskan air carrier accidents.

1. *The Thunderstorm*, United States Department of Commerce, p. 138.

2. Ibid., p. 85.

3. Ibid., p. 89.

Some Examples

Five aircraft were destroyed by being forced to the ground during the period studied. In 1953, a DC-3 flew into a severe thunderstorm near Marshall, Texas. Turbulence and gusts caused a loss of effective control, and the aircraft was forced to the ground. In 1954, a CV-240 flew into an area of severe turbulence and heavy icing conditions in Wyoming. The aircraft made a rapid descent and struck the ground at a high speed in a near level attitude. A few months later a DC-3 was observed turning toward a thunderstorm at 300 to 400 feet. About a mile from the point of penetration the aircraft struck the ground in a level attitude with a considerable downward or sink velocity, in an area where severe storm ground damage occurred. In another accident, a C-46 descended for unknown reasons into an area of severe turbulence and heavy ice. The aircraft was unable to regain altitude and crashed through trees on a mountain, while in a near level attitude.

The last accidents of this group where loss of control was indicated involved a C-46 which was reported missing near Mobile, Ala., in April, 1954. Thunderstorm activity with severe turbulence had been reported in the area of the accident. During a several month period, parts of the aircraft were washed ashore and examination of these disclosed no indication of malfunction or failure of the aircraft or its engines prior to impact.

The accidents where aircraft were destroyed by turbulence range from the C-46 in 1953, where the actual cause was established, to the C-46 near Mobile, where the actual cause may never be definitely established. However, in each of these accidents, there is evidence that turbulence was the primary factor leading to ground impact.

In all accidents where the aircraft received substantial or minor damage, passengers were injured. One of these accidents involved clear air turbulence. In the two accidents where the aircraft received substantial damage, the crash control system was damaged in one and the empennage damaged in the other. Air line records have revealed cracked wing spars during inspection; however, I found no record of a wing receiving a permanent set.

Study of Serious Injury Accidents Caused by Turbulence in Flight published by the Civil Aeronautics Board was written to show extent and seriousness of air carrier accidents caused by inflight turbulence. In this report, eighteen out of the forty four accidents reported occurred during visual flight rule conditions. This fact shows the danger of clear air turbulence to passengers and crew. Significant aircraft damage rarely occurred in accidents of this type.

How To Avoid Turbulence

Turbulence is often impossible for an air line pilot to avoid because there are no visual clues to areas of clear air turbulence, or because of air traffic control. Cumulus cells are often present in stratus cloud layers and can only be detected by radar. Turbulence may be avoided by the following methods:

▶ First: Avoid thunderstorms by visual reference, airborne radar, or reports from ground radar stations.

▶ Second: Advances in clear air turbulence prediction and pilot briefing may reduce damage caused by clear air turbulence.

▶ Third: Reduce the aircraft's airspeed to "speed through turbulence," when approaching areas of suspected turbulence.

▶ Fourth: When you find it necessary to enter a thunderstorm, enter it at 10,000 feet above the ground or less.

▶ Fifth: Don't fly into "light spots" or "greenish hued" regions in a thunderstorm. These are regions of severe turbulence and hail.

The problem of aircraft displacement by a draft from an assigned altitude is understandibly a very serious one. Especially in high density traffic areas where there is the danger of mid-air collision. "Displacement depends upon draft width and speed and the aircraft's airspeed. For an aircraft flying at 180 miles per hour, the displacement is not likely to exceed 2000 feet although displacement of 5000 feet may occur."[1] I found reports that aircraft may be carried down below two thousand feet above the ground where a downdraft's maximum width is reached. This condition would force a pilot to take corrective action to combat the draft which could result in an inadvertent stall close to the ground.

A downdraft containing heavy rain spreads out as it approaches the ground, as would a jet of water directed toward a flat plate. Measurements by the Thunderstorm project indicated significant downdrafts may exist at altitudes of less than 1,000 feet above the ground. Under a condition of this kind an aircraft can be forced to the ground. "The only place where downdrafts below the cloud base is likely to have a speed great enough to be hazardous to airplanes is in the main core."[2] Therefore, heavy rain areas near the ground should be avoided by visual reference or by using radar.

1. *The Thunderstorm*, United States Department of Commerce, p. 137.

Hail Damage

Hail is a serious hazard in thunderstorm flying. Although only three accidents caused by hail were reported during the period studied, I am sure many similar accidents occured during the period. Hail damage to aircraft consisted of dented sheet metal skin and a cracked windshield.

The formation of hail requires large quantities of water and strong updrafts to delay the fall of hail nucleus, long enough for it to acquire a heavy coat of ice. Therefore, hail usually occurs during the mature stage of a thunderstorm.

Hail may be avoided by circumnavigation of regions of high water content in a thunderstorm by visual reference or radar. Stay clear of "greenish hued" regions of a thunderstorm.

Use Of Airborne Radar

This study indicates that the most severe weather phenomenon occurs during the mature stage of a thunderstorm. Ground radar has been used for some time to observe thunderstorm heights to determine when it is in the mature stage. I believe airborne radar could be used by aircrews for the same purpose to aid inflight planning.

2. *The Thunderstorm*, United States Department of Commerce, p. 137.

The following range-height formula will give the elevation of a target above the earth using parameters of Bendix air-born radar.

$$\text{"he} = 6080R \text{ Sine } \Theta + 646 R^2$$

where

he = True height of a target in feet measured from the center of the

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beam axis

R = slant range observed on radar in nautical miles

Θ = angle of elevation of the center of the beam axis.

This formula may theoretically be applied in the following way to find the height of a thunderstorm above the flight altitude of an aircraft. Example:

First: Tilt the antenna up until the target fades off the screen. This angle may be called the "fade out angle."

Second: Correct the "fade out angle" to angle Θ which is read from the tilt knob. This correction would be + 5.9° on ½ of the beam width of 3.8°. Therefore, if a target fades out at an antenna tilt setting of 5.9°, then angle Θ would be 5.9° + 1.9° or about 7.8°. *(See Figure 1)*

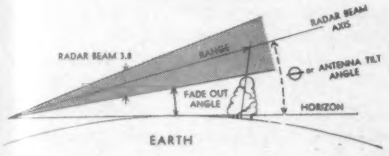


Figure 1

Third: Read the approximate elevation of the thunderstorm from a chart similar to the one below which was computed for the antenna tilt angle of 1° or "fade out angle" of — .9°. *(See Figure 2)*

Range	Angle Of Antenna -0- Tilt (Up) 1°
25K	408'
50K	6,760'
75K	11,409'
100K	16,960'
125K	22,427'
150K	30,285'

Figure 2

Conclusions

Ground and airborne radar used correctly can reduce the number of accidents caused by atmospheric phenomenon. All of the accidents studied were caused by turbulence, lightning, or hail which are coincidental of regions of high water content in thunderstorms. Accidents caused by clear air turbulence may be reduced in the future by better forecasting of regions where it may be present.

As Others See It:

Basic Operational Three Pilot Jet Crews As Reported In N. Y. Herald Tribune

"American Airlines said yesterday that in its view its decision to include a third pilot on jet aircraft does not represent "feather bedding"—unnecessary work granted in response to union demands.

The air line issued its explanation along with the report that its flight operations were 80 per cent of normal last night, and that service, stopped from Dec. 20 through last Saturday by a pilot's strike, would be completely restored this morning.

The air line said the decision to add a pilot to the current three-man pilot, co-pilot and flight engineer crew was based on experience of its supervisory pilots in 400 flight hours testing the Boeing 707 jet transport since Oct. 23. The third pilot provision was part of the strike-settling contract.

The air line, which reported that it made its "fourth man" decision on Dec. 1, twenty days before the strike began, said it acted "in the interest of highest safety." It said the primary duties of the third pilot, who could also relieve the first and second pilots, would be to handle communications, including radar, and in-flight log-recording requirements.

The air line said the faster jet speeds left considerably less time for such duties, previously performed by the captain and co-pilot. The company said, for instance, that the 2,451-mile jet-flight from New York to Los Angeles requires eighty-one air-ground radio contacts, each averaging fifty seconds."

Pilot Pay As Viewed By Paul Harvey Syndicated Columnist and News Commentator

"The ALPA picked a bad time to call a pilots' strike against American Airlines. It is understandable that they figured the pressure on the company was greatest when the traffic was heaviest.

But there is a "rest of the story." Before you too-eagerly trade jobs with that man in the cockpit, let's examine his position.

The air line pilot has as many employees depending upon him as the average plant manager of a 400-man factory. Further, his "factory in the sky" represents an immediate investment of $5,000,000 to $8,000,000.

The annual gross and net of his "factory" is not unlike most factories representing a similar investment on the ground, considering the rapid depreciation of his equipment.

So when you look at him as a "plant manager" rather than as a chauffeur, $20,000 a year is about par.

Now, however, of 14,000 air line pilots, only 700 are in the $20,000 class. Only the senior 5 per cent on the plush international runs rate that pay.

The average for co-pilots, for example, is $8,500 a year. Not $20,000.

And about that 85-hour month. That is flight time only. Would you be so eager to trade jobs with the air line captain if you knew you would be away from your home and family an average 340 hours a month?

"But it's such an easy job, just sitting up there sipping coffee and steering toward some exciting new horizon." Well, don't forget that 170 to 200 hours a month you will spend making out flight plans, refueling, doing turn-arounds and paperwork.

You will have to take two rigorous physical exams every year. Flunk one and you're unemployed.

Also you will bone up for and take two flight proficiency checks per year, plus a line check.

"But pilots make more money than some doctors and lawyers!"

That's true.

But he works ten years rising from co-pilot to high-pay captain. So both his education and his probationary period are as long, or longer than that of a doctor.

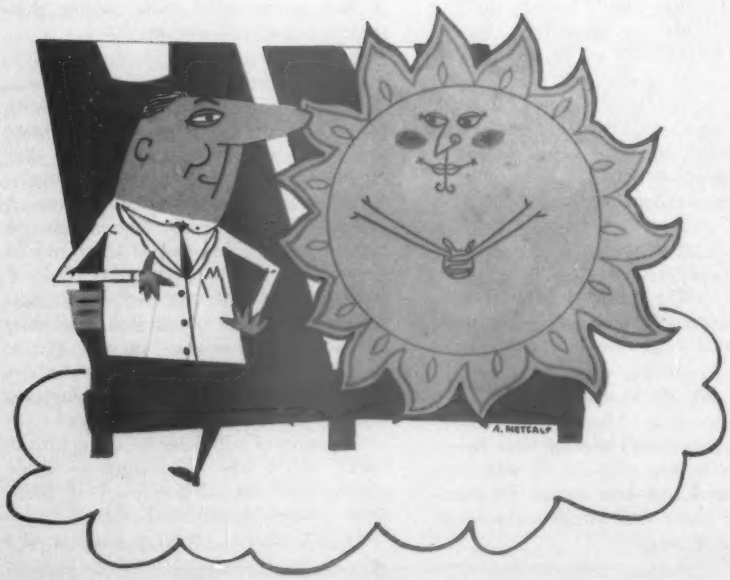
And his responsibility is no less. A doctor's mistake may cost a life. A pilot's mistake may cost a hundred lives.

"But," you say, "in spite of all that training—in spite of all that insecurity due to periodic exams—in spite of the long hours of dull routine—the study—the being away from home 80 hours a week—instead of your present 40.

"In spite of all these sobering drawbacks, you'd still be willing to trade places with the airline pilot if there were enough money in it. . . ."

That is the issue. What is "enough"?

IT'S ONLY A MATTER OF TIME



The Speed Of Travel In Jets May Lead To Unusual Experiences For Passengers And Pilots ,Too

By Tom Riedinger
Boeing Magazine

SOME people claim that time was invented so that others could be late. In the jet age, however, being late should become a lost art. According to estimates by Boeing, its 707 jet

airliners will decrease travel time by nearly one-half.

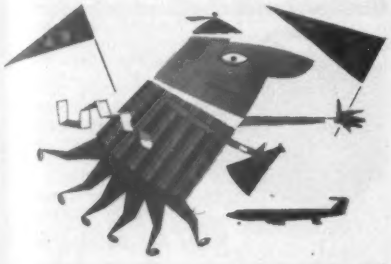
The speed of this jet travel will afford passengers many unique experiences, some of them a little startling.

A passenger will be able to fly around the world in less than two days. Depending upon the direction of travel, he will fly through either two or three days of varying length.

For example, a well-timed trip in an easterly direction might have a passenger departing Tokyo Sunday evening and flying into Monday over the Pacific. So far so good, but imagine the confusion when he crosses the International Dateline, loses contact with Monday and lands in Seattle on the same Sunday on which he left Tokyo. Then he will have to face Monday morning all over again, and you know what that's like.

A westerly flight, on the other hand, would have the passenger traveling with the sun. Because of the plane's speed and the time zones, only an hour's time would be lost every few thousand miles.

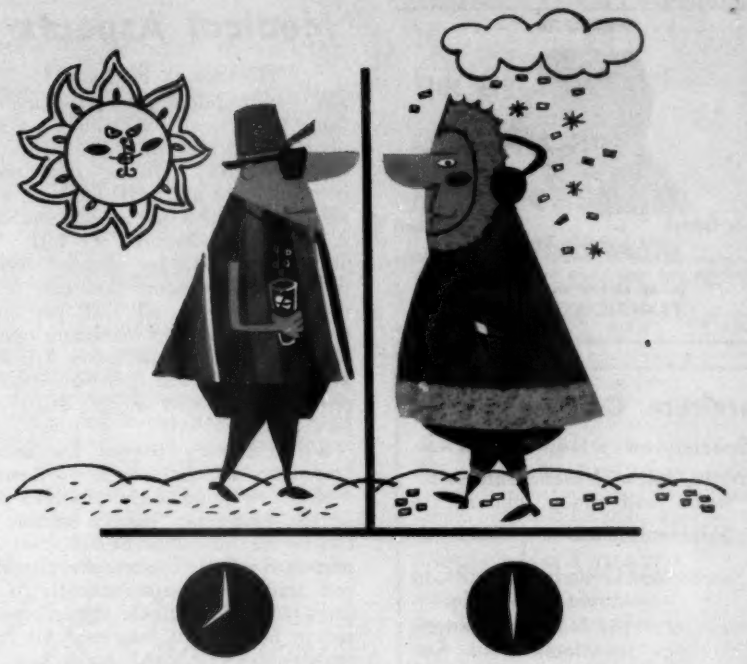
Crossing the International Dateline at a certain time would cut one day in half but would make the following day



nearly 40 hours long. This would be dandy for people who like four hours for lunch and who would enjoy watching the sunset all afternoon.

Such trips, due to the irregular length of days, may create gastronomic and sleeping problems for those who like three meals and eight hours of shuteye.

On an evening eastbound flight, a person could have dinner shortly after takeoff from Seattle at 4 p. m., or during the layover in New York for refueling and passenger loading at 8:12



p. m. stomach time (11:12 p. m. New York time). He would arrive in Paris at noon, Paris time, although his stomach and mind might be crying, "Good grief! It's only 3:10 a. m."

Shorter flights, too, offer unique situations. The inveterate night clubber could catch the early show in Paris and arrive in New York for a later performance—the result of losing only an hour while crossing the Atlantic.

Similarly, a sports fan could watch the Orange Bowl football game in Florida and reach Los Angeles in time to witness the second half of the Rose Bowl game on the same afternoon.

Unfortunately, such opportunities will not be available for those who fly mainly in a northerly or southerly direction, but they can enjoy the fact that their trip will last only half as long as at present.

For people who like the unassuming boast, jet travel offers numerous opportunities. On beginning a talk in Mexico City a speaker might remark, "I'm afraid I left my notes in London this morning." Or a tourist eating breakfast in Copenhagen could say casually, "I've decided to join mother for lunch in Rome."

All this places a greater burden on passenger agents. They must be prepared not only to plan connecting flights but to suggest eating schedules, give the time of day for various destinations, mention radical changes in climate and other novel situations incidental to jet-airliner travel.

En route, the simple question "What time is it?" may be answered in several ways, depending on the passenger's wish to know the time in regard to his point of departure, present location or destination. This problem exists today, but air line personnel will find that changes come faster in the jet age.

Perhaps one conclusion should not be overlooked. For people having a "bad" day, an easterly flight will make it pass quickly; "good" days can be lengthened by going west.

You see, it's only a matter of time!

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Medical Aspects Of Jet Flying . . .

(Continued on Page 5)

age consumption per crew member using this system is 4.25 liters per minute standard pressure and temperature, dry (S.P.T.D.). During post-decompression flight at 15,000 feet, the average consumption per crew member is 2.1 liters per minute S.P.T.D. The automatic passenger oxygen system provides a continuous flow rate of 3.4 liters per minute S.P.T.D. per outlet during descent from maximum operating altitude, and thereafter 1.7 liters per minute S.P.T.D. per outlet during post-decompression flight at 15,000 feet.

Supplementary oxygen for invalid passengers is available from separate outlets connected to the pipelines used in the emergency oxygen system. A continuous flow rate of 2.5 liters per minute S.P.T.D. is normally provided, and this doubles automatically to 5.0 liters per minute should the emergency system be brought into use. All these figures are calculated on a basis of pulmonary ventilation rate of 15 liters per minute.

Special Considerations

Experience has shown that glare does not present as great a problem as was at first anticipated. It can easily be reduced by cockpit curtains and by the use of sun glasses. New thoughts on the best color background for instrument panels are under consideration and grey has been given extensive trials with encouraging results. Space myopia, a condition brought about by the absence of focusing points for the eyes at high altitude, does not present a serious problem because normal focusing is regained during descent and well prior to landing, but it must be taken into consideration where there is heavy traffic density at altitude. Closing speeds of modern jet aircraft can be very great and, because there is a specific time lag for eyes, ears and muscles in reacting to any sensory impression received, this must be taken into consideration where airport traffic control systems operate. This involves adequate vertical, as well as horizontal, separation, the physiological time lag only allowing four to five seconds for avoiding action at a range of 1 to 2 miles. This is a matter which requires serious consideration by air traffic control authorities at an early date and underlines as well the importance of absolute clarity of instrument presentation and lighting in the cockpit.

In addition to these problems, there

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are those of acute pain in the ears and sinuses if an emergency descent is necessary, and decompression sickness in the event of continued flight at altitude. It is difficult for a pilot who is suffering acute pain in the ears not to slow down an aircraft's descent, even if it might be a matter of life or death for the passengers.

Contrary to popularly held beliefs exposure to radiation does not constitute a hazard. It has been calculated that a pilot putting in 1,000 hours a year at 40,000 feet, would have to keep on flying for about 150 years to absorb the maximum gonadal dose. These hazards will, however, become more serious when aircraft fly above 70,000 feet.

Summary

Jet aircraft are straightforward to fly and their flying technique does not require exceptional standards of physical or mental fitness. If anything, the danger is that their good flying characteristics could lead to a mistaken impression by non-flying executives that they are easier aircraft to fly than current piston engine types. This view must not be allowed to gain credence. The operation of flight time limitations, stacking at airports, fuel reserves, and the tiring effects of manual flying of such a sensitive aircraft, should the automatic pilot fail, must be given due consideration.

The ideal pilot for operation of jet aircraft is one who is methodical and clear thinking, has a mobile mind, and who fits in readily with a team. Good flight planning is required and a high standard of training and indoctrination is most desirable. Figures available show, if anything, that the sickness rate among jet pilots is slightly lower than that in piston engine aircraft.

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